MARBLE SLURRY DUST AND WOLLASTONITE–INERT MINERAL ADMIXTURES FOR CEMENT CONCRETE

RENU MATHUR*, A.K. MISRA* & PANKAJ GOEL**

SYNOPSIS

Engineering characteristics of concrete mixes incorporating marble slurry dust (marble waste), wollastonite micro fibres (natural mineral), fly-ash and silica fume were studied in the laboratory.

Workability of the concrete mixes was found to diminish as the proportion of Marble Slurry Dust (MSD) increases from 30-60 per cent as partial replacement of sand, the fine aggregate. However, the workable mixes prepared using super plasticizers have highly enhanced compressive strength and improved flexural strength. Further, to such concrete mixes when silica fume is incorporated as partial substitute of cement and wollastonite as that of sand, there is sharp increase in the flexural strength of concrete. Improvements in compressive and splitting tensile strength were also observed. Water absorption, drying shrinkage and abrasion were found to decrease with the addition of these fine mineral admixtures and concrete so prepared remains unaffected by sulphate waters and alternate freezing and thawing.

INTRODUCTION

In the recent past use of supplementary cementitious materials like fly-ash, silica-fume, blast furnace slag and also of inert fillers in cement and concrete has increased several folds [1]. It is well known that the use of these materials significantly reduces the permeability and diffusivity of concrete, thus improving its long-term durability. Aggregates constitute more than seventy per cent of the volume of concrete. Since sources of good quality natural aggregates are fast depleting, the concrete industry needs to brace itself to use locally available marginal aggregates. Presently, major metropolitan cities and towns in India are experiencing a shortage of good quality sand, and concrete producers are compelled to fetch it from longer distances.

Here, the use of manufactured sand in place of river sand can be construed as an environmental-friendly measure and hence should be encouraged. It may also be worthwhile to explore the possibility of using recycled aggregates[2, 3] from demolition wastes and other unexplored industrial wastes as fine/coarse aggregates in the vicinity of the units producing such wastes. One such unexplored industrial waste is marble slurry dust that can replace high proportion of the fine aggregate in cement concrete.

5-6 million tonnes of marble slurry dust is generated per annum in the State of Rajasthan. The indiscriminate disposal of this slurry has posed severe threat on the environment, eco-system and health of people. It may, therefore, be appropriate to carry out a techno economic feasibility of using this waste in civil works like roads and concrete works. Mention of finally divided inert mineral admixtures has also been made in the ACI committee report [4].

A study conducted in past on the potential of marble slurry dust as partial substitute of sand (fine aggregate) in concrete[5,6], revealed that water requirement of a concrete mix increases as the proportion of MSD increases but have no detrimental effect on strength and durability of concrete so long as the cement content per cubic meter of concrete is kept unchanged. In the present study, effects of different admixtures *viz.* fly - ash, silica - fume and wollastonite mineral powder on the properties of MSD concrete have been explored. The results have been presented and possible benefits of using marble slurry, silica fume and wollastonite have been discussed in the paper.

1.1 Experimental Materials

Marble slurry dust (Sp.gr. 2.7) : Marble slurry dust collected from a marble cutting unit in Udaipur, comprises of very fine particles (100% passing 75 micron sieve). It consists of calcium carbonate associated with small quantities of magenesium

* Scientist
** Technical Assistant } Central Road Research Institute, New Delhi.

carbonate. The active CaO/MgO was found to be less than 5 per cent. It is insoluble in water and does not show any swelling characteristics.

Wollastonite (Sp.gr. 2.9) : It is a natural, inert, acicular, white silicate mineral of high modulus of elasticity. It forms from the interaction of lime- stones with the silica, SiO_2 in hot magmas. It is basically calcium meta silicate.

It is available in 400 to 10 micron size and aspect ratios (length : diameter) of 3:1 to 20:1. In the present study, the natural wollastonite micro-fibre, aspect ratio (3:1) and 100% passing through 75 micron sieve size, was used.

Fly-Ash: It was collected from the electrostatic precipitators of Thermal Power Plant, Dadri,India.

Silica- fume/Micro-silica: Micro-silica is a mineral of ultrafine, amorphous glassy spheres of silicon dioxide, produced during the manufacture of silicon or ferrosilicon.

Coarse& fine aggregate: Blue quartzite, sp. gr. 2.62, 20 mm maximum size as coarse aggregates and natural sand, sp. gr. 2.62 and fineness modulus 2.60 were used as fine aggregates.

Super plasticizer/High-Range Water Reducing Agent: Glenium B 233 (pH , 7-8; Chloride content, Nil; Relative density, 1.1 at 20°C) manufactured by Master Builders Technology (MBT) India Pvt.Ltd., was used in the study. It was a carboxylic ether polymer with long lateral chains.

1.2. Experimental Methodology Adopted

A concrete mix was designed as per IRC-44(1976)[7] and IS: 10262 (1982)[8]. with the available materials viz. cement, sand and aggregates in the laboratory for a compressive strength of 350 kg. per sq.cm. at 28-days for a compacting factor of 0.85.

Mixes were also designed by the partial replacement of sand i.e. fine aggregate by 30, 40, 50, and 60 per cent by mass of marble slurry dust. The general condition/workability of the mixes so prepared were observed. To make the mixes workable for paving applications. super plasticizer doses were optimized.

Further, different mixes were designed by the incorporation of fly-ash and silica- fume as partial substitute of cement in concrete containing marble slurry dust.

To evaluate the effect of wollastonite natural fibres, it was used as a partial substitute of sand in the concrete mixes containing 10 % silica fume as partial substitute of cement and marble slurry dust as partial replacement of sand.

The cube (10 cm x 10 cm x 10 cm), beam (10 cm x 10 cm x 50 cm) and cylinder (dia.- 15 cm, h- 30 cm) specimens prepared for various tests were cured at 90 per cent humidity for 24 hours and then soaked in water for the desired periods before their testing.

To determine the water absorption, 28 day soaked concrete cube specimens from each set were weighed in surface dry condition and then dried in electric oven at 110±1°C for 24 hrs. The loss in weight of specimen was determined and water absorption was expressed as per cent loss in weight of the specimen.

The drying shrinkage of the concrete beam specimens (30 cm x 7.5cm x 7.5 cm) were conducted as per IS:1199-1959[9]. Splitting tensile strength of concrete was determined as per IS: 5816-1999[10]. Abrasive resistance characteristics of concrete under physical effects were determined as per IS: 9284-1979[11].

To assess the durability of concrete, cube specimens from each set after 28 day soaking were subjected to two sets of durability cycles viz. freezing-thawing and immersion in sodium sulphate solution.

Freezing-thawing cycle – One such cycle comprised of freezing the specimen at – 10°C±2°C for 6 hours in an environmental chamber and thawing in air at 27°C±2°C for 18 hours.

Immersion in sodium sulphate solution– This cycle consists of immersion of the test specimen in 5 per cent sodium sulphate solution for 18 hours and drying in air at 27°C±2°C for 6 hours.

The test specimens were subjected to 30 such cycles and after that their compressive strengths were determined. Compressive strength of cube specimens from the same set which were continuously cured in water were also determined to compare the strength results.

2. RESULTS AND DISCUSSION

The mixes containing MSD as partial substitute of sand become progressively sticky and dry with its increasing proportions in the concrete mix. For the desired workability several super plasticizers were tried and with the selected one, doses were optimized for different mixes. The mixes containing more than 40 per cent MSD were highly cohesive and became immobile and surface finishing of such mixes was achieved with difficulty. The general condition/ workability of the mixes before and after addition of super plasticizer have been summarised at Table 1.

The results of compressive strength are shown at Table 2. It can be seen that there is remarkable improvement (44%) in the 28 day compressive strength of concrete when 40% sand is replaced by MSD. It can also be seen that the improvement in compressive strength at 7-day is more as compared to that observed at later ages *viz.* 28 and 90 days. It is due to fast hydration of cement in presence of inorganic mineral[12] *viz.* marble dust. Improvement in flexural strength as a result of incorporation of MSD in the concrete mix can also be seen (Table 3). However, beyond 40 per cent substitution of sand by MSD, the mixes became highly sticky and their proper compaction in field conditions may pose problems as extra efforts may be needed for the same.

Table 2. Effect of Marble Slurry Dust as Partial Replacement of Sand on Compressive Strength of Concrete

MSD (%)	Compressive Strength (Kg/cm²)		
	7 day	28 day	90 day
0	260	350	420
30	370	461	510
40	392	507	588
50	389	489	550
60	365	449	489

Table 3. Effect of Marble Slurry Dust as Partial Replacement of Sand on Flexural Strength of Concrete

MSD (%)	Flexural Strength (Kg/cm²)	
	28 day	90 day
0	56	65
30	64	69
40	66	73
50	65	72
60	64	70

Table 1. General Condition and Workability of Wet Concrete Mixes incorporating Marble Slurry Dust as Partial Replacement of Sand

MSD (%)	SP(%)	General Condition	CF	SP(%)	General Condition	CF
0	0	Good	0.87	0	Good	0.87
30	0	Tough	X	0.45	Good	0.94
40	0	Tough	X	0.45	Good	0.89
50	0	Dry/Tough	X	0.50	Cohesive	0.84
60	0	Dry/Tough	X	0.60	Cohesive	0.85

X - Compacting factor could not be determined

The results of water absorption and abrasion loss are shown at Table 4. From the results it can be seen that as the proportion of MSD increases, water absorption decreases, because of dense packing of the concrete, however above 50 per cent it increases due to improper compaction of the mix resulting in air voids.

TABLE 4. EFFECT OF MARBLE SLURRY DUST AS PARTIAL REPLACEMENT OF SAND ON WATER ABSORPTION AND ABRASION LOSS OF CONCRETE

MSD (%)	Water absorption (%)	Abrasion loss (%)
0	3.6	0.150
30	3.5	0.140
40	3.0	0.136
50	2.7	0.140
60	3.9	0.143

Similarly, poor surface finish of the concrete specimen that was achieved when more than 40 per cent MSD was incorporated, have resulted in more abrasion as was seen from the results in Table 4.

Fly-ash addition to concrete mixes containing marble slurry dust resulted in the ball formation with the mortar coating the coarse aggregates. A number of super plasticizers were tried but no improvement was observed in the condition of mix.

On the other hand, the mixes prepared by incorporation of silica fume and wollastonite in marble dust concrete were highly workable with optimum super plasticizer doses. The details of concrete mixes designed by incorporation of silica fume and wollastonite micro-fibres in the concrete mixes (containing optimum quantity of marble slurry dust) as partial substitute of cement and sand respectively are shown at Table 5.

The results of compressive strength of the mixes studied are shown at Table 6. From the results it can be seen that 1-day strengths of mixes II & V are very high as compared to other mixes. It is due to the presence of minerals like marble dust and wollastonite that promote rate of hydration of cement. In mixes III & IV, due to the presence of silica fume as 10% replacement of cement, the pozzolonic reaction takes place and hence early age strengths are low, however the ultimate compressive strength of these mixes are more than that of mix V which contains only wollastonite.

From the results at Table 7, it can be seen that there is vast improvement in the flexural strength of concrete containing silica fume (10% substituted for

TABLE 5. EFFECT OF MARBLE SLURRY DUST, FLY-ASH, SILICA FUME AND WOLLASTONITE ON WORKABILITY OF CONCRETE

Mix No.	Details of concrete mix	Super plasticizer dose (%)	Compacting Factor
I	Control Mix	Nil	0.87
II	40% Sand replaced by marble slurry dust	0.45% by wt. of cement	0.92
IIIA	10% cement replaced by Fly-ash & 40% sand by marble slurry dust	—	——
III	10% cement replaced by silica fume & 40% sand by marble slurry dust	0.48% by wt. of cement & Silica fume	0.96
IV	10% cement replaced by silica fume, 30% sand by marble dust & 10% sand by wollastonite	0.50% by wt. of cement & silica fume	0.88
V	30% sand replaced by marble slurry dust & 10% sand by wollastonite	0.45% by wt. of cement	0.83

— Workable mix could not be prepared

TABLE 6. EFFECT OF MARBLE SLURRY, SILICA FUME AND WOLLASTONITE ON COMPRESSIVE STRENGTH (Kg/cm²) OF MSD CONCRETE AT DIFFERENT AGES

Mix	1 day	3 day	7 day	28day	90 day	180 day
I	73.5	185.0	260.0	350.0	420	472.5
II	108.6	277.8	392.0	507.0	588	608.0
III	76.0	235.0	345.0	552.0	590	668.0
IV	78.0	245.7	351.0	548.0	621	673.0
V	151.0	338.0	396.0	528.0	550	600.0

I. Control Mix
II. Sand replaced by 40 per cent marble slurry dust
III. ement replaced by 10 per cent silica fume and sand by 40 per cent marble slurry dust
IV. Cement replaced by 10 per cent silica fume; Sand by 30 per cent marble slurry dust and 10 per cent wollastonite
V. Sand replaced by 30 per cent marble slurry dust and 10 per cent wollastonite

TABLE 7. EFFECT OF SILICA FUME AND WOLLASTONITE ON FLEXURAL STRENGTH (Kg/cm²) OF MSD CONCRETE AT DIFFERENT AGES

Mix	28 day	90 day	180 day
I	56.0	65.0	70.0
II	64.0	73.0	75.0
III	70.0	75.0	79.0
IV	85.0	87.0	88.0
V	67.0	72.0	75.0

TABLE 8. EFFECT OF SILICA - FUME AND WOLLASTONITE ON SPLITTING TENSILE STRENGTH (Kg/cm²) OF MSD CONCRETE

Mix	28 –day, Splitting tensile Strength
I	43
II	47
III	49
IV	50
V	46

cement) & wollastonite as 10% replacement of fine aggregate (mix IV). The improvement in the flexural strength is due to the acicular structure and high modulus of wollastonite mineral. This is important to note that there is no improvement in the flexural strength of mix V which also contains 10% wollastonite as partial substitute of sand. From these results it is reveled that wollastonite is effective only in presence of silica fume otherwise it will give improvement to the extent of a fine packing inert material. This is further supplemented from the results of splitting tensile strength of the mixes (Table 8). The mix IV, containing both silica fume and wollastenite has very high tensile strength as compared to that of mix V which contains only wallastonite. The results of drying shrinkage of various mixes are shown at Table 9.

When the specimens from concrete mixes I to V, were subjected to alternate freezing- thawing and sodium sulphate cycles, it was observed that the strength of specimens subjected to these cycles were comparable to the strength of those continuously soaked in water from the same set. Thus it is revealed

TABLE 9. EFFECT OF SILICA – FUME AND WOLLASTONAITE ON DRYING SHRINKAGE OF MSD CONCRETE

Mix	% Drying Shrinkage.
I	0.09
II	0.085
III	0.048
IV	0.041
V	0.072

that marble slurry dust and wollastonite have no adverse effect on the durability characteristics of concrete.

TABLE 10. EFFECT OF FREEZING-THAWING AND SOAKING IN SULPHATE SOLUTION ON COMPRESSIVE STRENGTH OF MSD CONCRETE CONTAINING SILICA – FUME AND WOLLASTONITE AS ADMIXTURES

Mix	Compressive Strength (kg/cm^2) of concrete		
	Continuously soaked in water	After F/T cycles	After Sulphate cycles
I	406	402	400
II	585	583	575
III	629	609	600
IV	620	605	595
V	594	585	580

3. CONCLUSIONS

- Sand can be partially replaced by marble slurry dust in making cement concrete mixes.
- Optimum quantity of sand that can be replaced by marble slurry dust is around 40 per cent.
- Replacement of sand by marble dust results in increased water requirement for the desired workability of concrete mix. Keeping same amount of water per cubic meter of concrete, the workability can be achieved by using super plasticizer doses.
- Remarkable improvements in compressive strength can be achieved by substitution of 30-40 per cent sand by marble dust. Improvement in flexural strength were also observed.
- Reduction in water absorption and abrasion were also found when marble slurry is incorporated in concrete mixes by partial replacement of sand.
- When 10% cement is replaced by silica fume & 10% fine aggregates (sand and marble dust) are replaced by wollastonite, there is vast improvement in the flexural strength of concrete.
- The concrete mixes containing silica fume, wollastonite and marble slurry dust are durable against alternate freezing –thawing and sulphate attack.

RECOMMENDATIONS

1. In the adjoining areas of marble cutting units, natural sand up to 40 percent should be replaced by marble slurry dust in cement concrete works.
2. In applications where high flexural strength is required (roads, airfields etc.) use of wollastonite natural fiber should be encouraged.

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